

Title:

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Inelastic neutron scattering studies on UNiGe

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Abstract

We measured the inelastic neutron scattering response of UNiGe at various temperatures using incident beam energies of 25 and 100 meV. Below $T_N = 50$ K, there is evidence for the formation of a gap as indicated by reduced scattering close to the elastic peak. Furthermore, we find an excitation around 30 meV in addition to the phonon background for temperatures below 130 K. The results are discussed in terms of spin waves with formation of a gap in the excitation spectrum below T_N .

Keywords: inelastic neutron scattering, spin waves, uranium compounds

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A very prominent parameter for the magnetism in uranium compounds is strong $5f$ -ligand hybridization, which is believed to be the origin of the magnetic anisotropy in these materials [1]. Here, we consider the case of UNiGe, where the magnetic anisotropy within the b - c plane is much weaker compared to the a -axis anisotropy. UNiGe undergoes two antiferromagnetic transitions at around 50 K (incommensurate magnetic order) and at 42 K (commensurate order) [2].

Considering the possible influence of low-energy magnetic excitations on the bulk properties of a material leads to the concept of spin waves. Having in mind the strong magnetic anisotropy in uranium compounds, we may expect a gap in the energy spectrum of such excitations. In the planar-anisotropy case, where the in-plane anisotropy is ‘small’ (like UNiGe), one expects to observe spin waves or similar excitations with an energy gap Δ , which will give rise to an exponential term due to electron-magnon scattering in the temperature dependencies of the electrical resistivity and the specific heat [3]. Bulk investigations indeed revealed such exponential contributions in UNiGe with an energy gap $\Delta = 40$ K [4].

We performed inelastic-neutron-scattering studies using the inelastic spectrometer PHAROS at the Manuel Lujan jr. Neutron Scattering Center, Los Alamos National Laboratory, to test the possibility of spin waves in UNiGe. The experiments were done on 30 gram of polycrystalline UNiGe at seven different temperatures between 26 and 150 K using incident beam energies of 25 and 100 meV. Data were taken using a low-angle detector bank, which did not allow for any dispersion study because of the limited \mathbf{Q} coverage.

In Fig. 1, we display the inelastic-scattering response with $E_i = 100$ meV at four different temperatures: 26 K (commensurate phase) and 45 K (incommensurate phase) as well as 100 K and 150 K (paramagnetic phase). There is clear evidence for additional quasielastic scattering, in particular at higher temperatures. It has been argued that in uranium compounds there may be contributions from quasielastic scattering because of hybridization of the $5f$ electrons with the conduction electrons [5]. Quasielastic scattering is found also at lower temperatures, but reduced scattering indicates the formation of a ‘hybridization gap’ below T_N . Keeping in mind the intimate connection between $5f$ -ligand hybridization and magnetism, such gap may cause subsequent gapping in the magnon-excitation spectrum. Using $E_i = 25$ meV (not shown), we were able to determine that the size of the gap is about

6 meV (≈ 70 K), which is somewhat larger than the values for Δ from bulk measurements.

In addition, we find a clear excitation at 30 meV at low temperatures. As can be seen in Fig. 2, there seems to be little dependence of its location with temperature, while the integrated intensity decreases with increasing temperature until it is barely visible at $T = 150$ K. This behavior excludes that the excitation is of phonon-origin, thus it is magnetic. The observed temperature dependence of the excitation is inconsistent with the one expected for a simple single-ion crystal-field excitation, thus we speculate that it is due to spin waves. However, spin waves are rarely observed for temperatures above the ordering temperature, and in UNiGe the excitation persists up to 120 K (more than twice the value of T_N). On the other hand, spin waves far above the ordering temperature have been established in some low-dimensional systems [6], and similar behavior may not be inconceivable in uranium compounds due to their large magnetic anisotropy.

In summary, we found some evidence for spin waves in UNiGe. Spin waves exist already at temperatures substantially above T_N , and a gap in the magnon-excitation spectrum forms at T_N . Confirmation of the above picture will require a detailed analysis of the dispersion curves using single-crystalline UNiGe. Since $5f$ -ligand hybridization is expected to contribute to the spin-wave stiffness, this would provide some insight how spin waves propagate in systems with essentially delocalized $5f$ moments.

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Figure Captions:

Fig. 1: Inelastic-scattering response of UNiGe using 100-meV incident energy at four different temperatures. The solid lines represent Gaussian fits of the 30-meV excitation after subtraction of the background, the elastic and the quasielastic contributions.

Fig. 2: Temperature dependence of a) the position of the excitation and b) the integrated intensity of the 30-meV excitation in UNiGe.

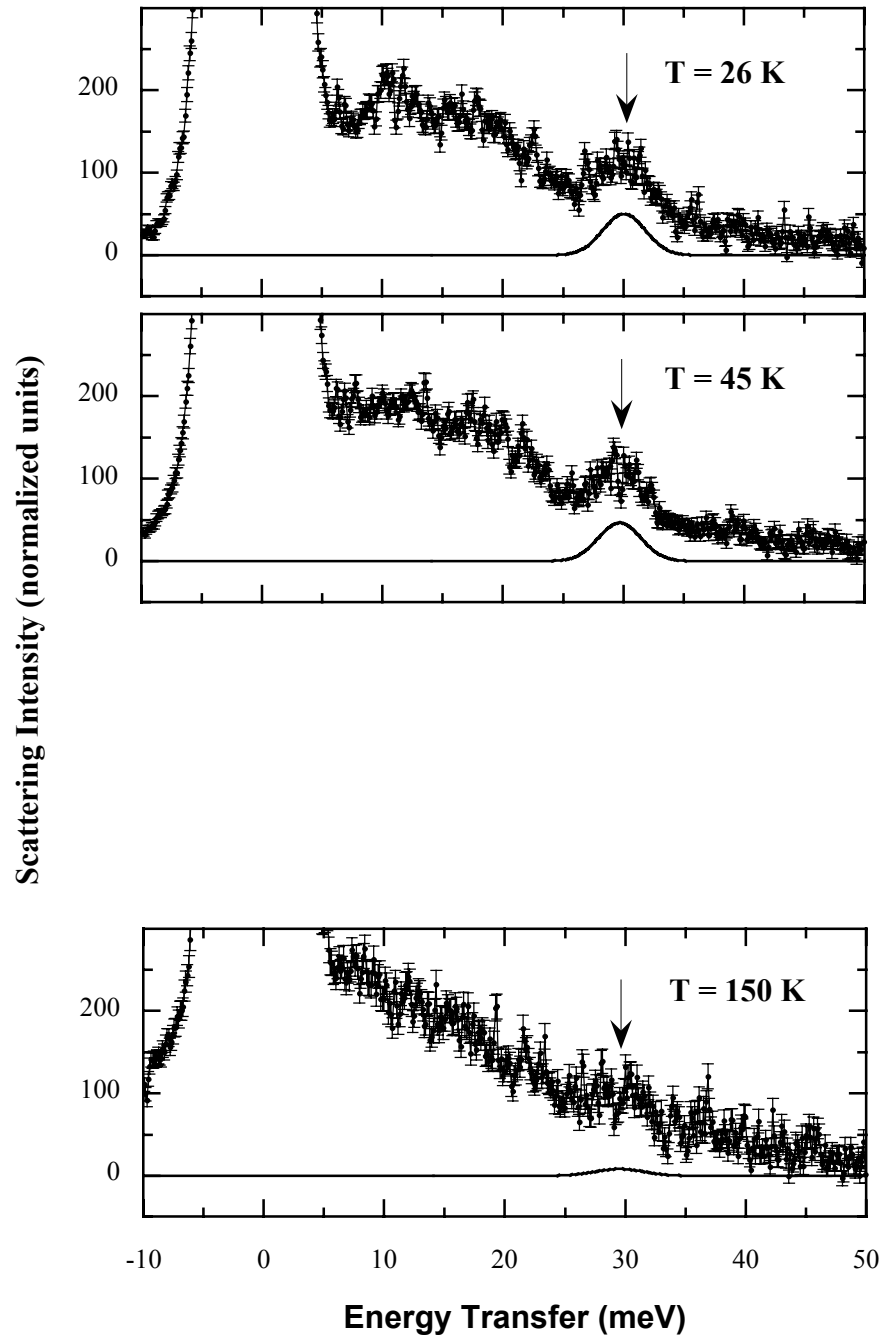


Fig. 1: H. Nakotte et al., Inelastic neutron scattering studies on UNiGe

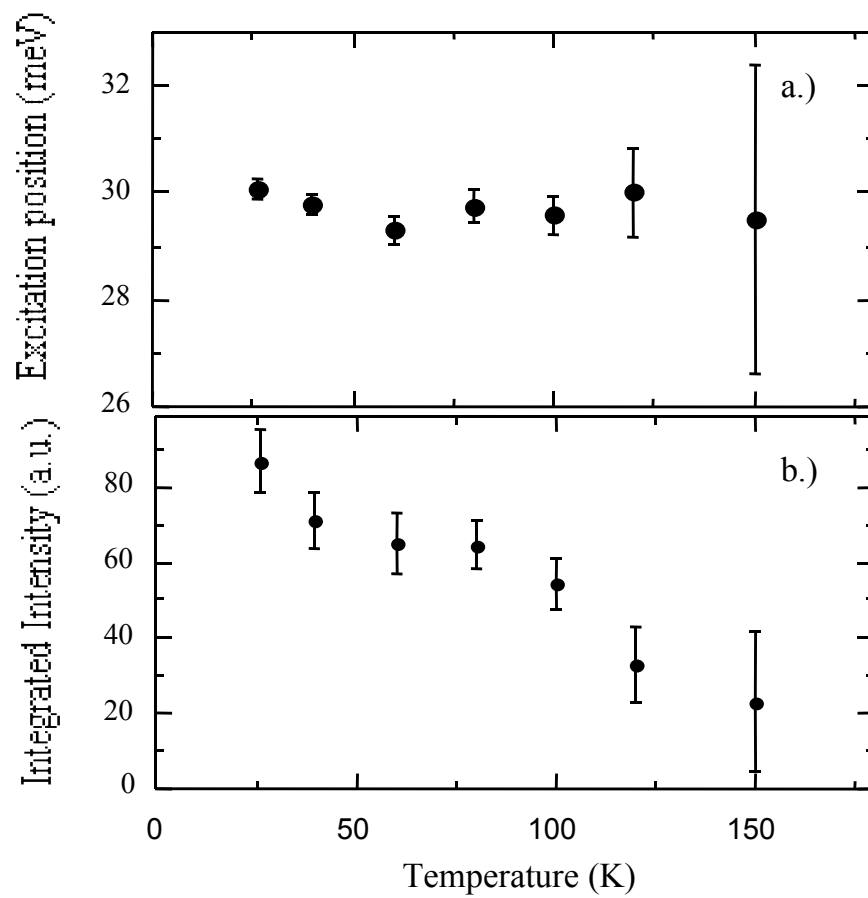


Fig. 2: H. Nakotte et al., Inelastic neutron scattering studies on UNiGe